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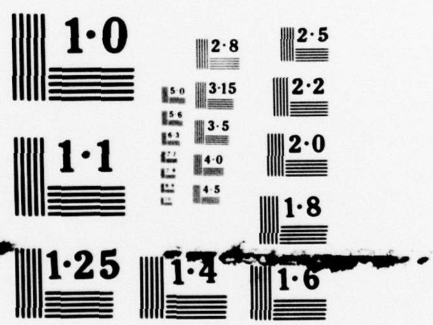
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study was conducted to determine the minimum update rate of a forcing function display required for the operator to approximate the tracking performance obtained on a continuous display. Previous studies ~~(see review by Frost, 1972, p.287)~~ using time on target as a measure of performance, obtained a breakdown in performance around 15 samples per second. In this study, frequency analysis was used to determine whether there was an associated change in the transfer function characteristics of the operator. It was expected that as the

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forcing function display update rate was reduced, from 120 to 15 samples per second, the operator's response to the high frequency components of the forcing function would show a decrease in gain, an increase in phase lag, and a decrease in coherence.

TWO DIMENSIONAL EYE TRACKING: SAMPLING RATE OF FORCING FUNCTION

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INTRODUCTION

This study was conducted to determine the minimum update rate of a forcing function display required for the operator to approximate the tracking performance obtained on a continuous display. Previous studies (see review by Frost, 1972, p. 287) using time on target as a measure of performance, obtained a breakdown in performance around 15 samples per second. In this study, frequency analysis was used to determine whether there was an associated change in the transfer function characteristics of the operator. It was expected that as the forcing function display update rate was reduced, from 120 to 15 samples per second, the operator's response to the high frequency components of the forcing function would show a decrease in gain, an increase in phase lag, and a decrease in coherence.

APPARATUS

The forcing function, in each dimension, consisted of the sum of nine sine waves and simulated a Gaussian noise passed through a second order filter with a roll-off frequency at 1 Hz. The forcing function was generated at rates of 120, 60, 30, or 15 samples per second and presented on the screen at these update rates. An optical projection system consisting of a low power laser and a pair of galvo-mirrors rear projected the forcing function onto a cloth screen in the form of a spot of red light randomly moving in two dimensions about a center spot marked on the screen. The maximum excursion of the forcing function was $\pm 5°$ visual angle in azimuth and elevation, as viewed by the subject (S). The $\pm 5°$ visual angle positions were also marked on the screen and, along with the center spot, served as

calibration points for both the forcing function and S's eye movement response. The subject tracked the forcing function from a position on the opposite side of the screen from the optical projections system and equidistant from the screen.

The subject's eye line-of-sight was computed using the AMRL Honeywell Remote Oculometer. For a complete description of the Oculometer, see Merchant, et. al., 1974. Calibration of the Oculometer prior to each tracking run was accomplished by using a second optical projection system positioned adjacent to the forcing function optical projection system. The movement of the laser spot generated by this second system corresponded to the subject's eye line-of-sight. The Oculometer-driven laser spot was turned off during the tracking run.

Five channels of a seven channel 1/2-inch Ampex 300 instrumentation tape recorder were used to record: (1) time code, (2) horizontal forcing function, (3) vertical forcing function, (4) horizontal eye movements, and (5) vertical eye movements.

PROCEDURE

Four students, two male, two female, from the University of Dayton served as subjects for this study. Each subject tracked the forcing function twice at each sampling rate (eight tracking runs per subject) in a partially balanced design. The data for each subject was collected in two test sessions of four tracking runs each. After seating the subject, the operation of the Oculometer was checked and calibrated. The subject was instructed to sit in a natural, comfortable position. The only constraint placed upon the subject was the instruction to refrain from making large head movement. The subject was instructed to follow (pursue) the moving spot of light with his eyes as the spot moved on the screen. The subjects were screened for uncorrected 20/20 vision. Between runs subjects were given a short rest.

RESULTS

Frequency analyses of the data from the four subjects were accomplished using an IBM 370 Computer and the BMD X92 program. For each run the power spectral density of the forcing function, the power spectral density of the eye response output, the cross power spectral density, the cross correlation, the coherence, and the transfer functions in gain and phase were computed. The data for the two runs for a given sampling rate condition were averaged, for each subject, at each of the nine sine wave component frequencies of the forcing function.

The average transfer function gain, averaged across subjects, for each of the four sampling rates, are presented in Figure 1 (Horizontal) and Figure 3 (Vertical). No differences attributable to sampling rate are present.

The average transfer function phase, averaged across subjects, for each of the four sampling rates, are presented in Figure 2 (Horizontal) and Figure 4 (Vertical). An increase in transport delay of approximately 30 msec was observed at the 15 samples per second update rate for both the horizontal and vertical tracking data.

The coherence data averaged around .98 with a slight drop off at the high frequencies and showed no differences attributable to the sampling rate of the forcing function.

DISCUSSION

The lowest update rate used in this study (15 samples per second) was not low enough to have an appreciable effect upon the transfer function characteristics of the operator. Further research is planned using lower update rates. Expected changes at the high frequency sine waves components of the forcing function not observed in this study may be observed at lower update rates. A time on target analysis of the data is planned to determine whether the results of this study correspond with the results previously reported.

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2. Merchant, John, Morrissette, Richard, and Porterfield, James L., "Remote Measurement of Eye Direction Allowing Subject Motion Over One Cubic Foot of Space," IEEE Transactions in Biomedical Engineering, Vol BME-21, No. 4, July 1974.

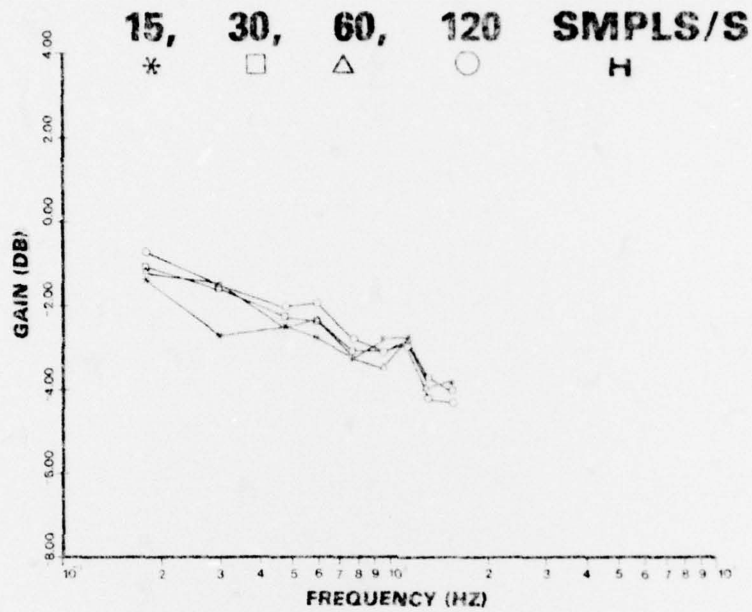

Figure 1. Horizontal Gain as a Function of Update Rates

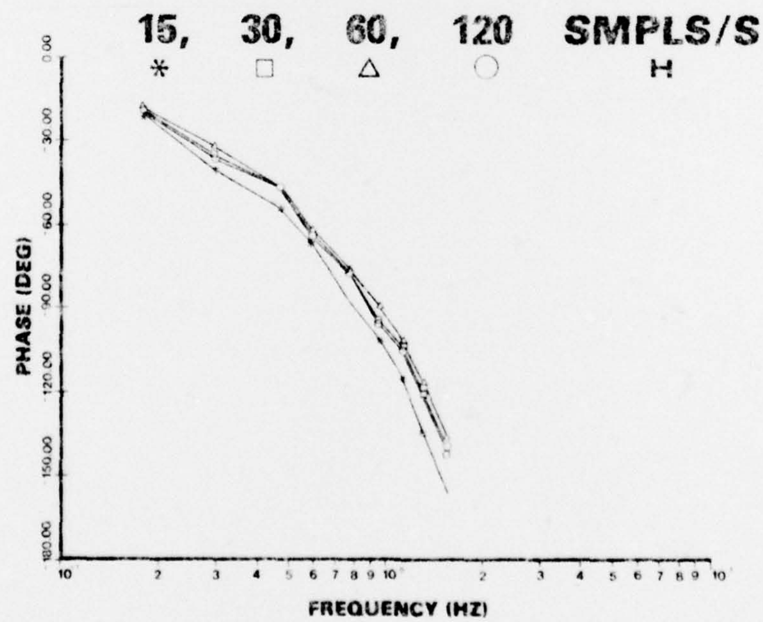

Figure 2. Horizontal Phase as a Function of Update Rates

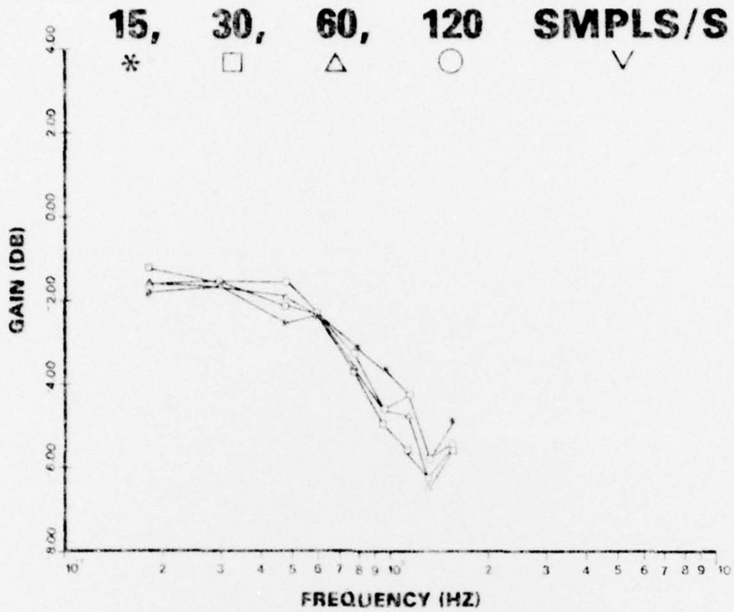

Figure 3. Vertical Gain as a Function of Update Rates

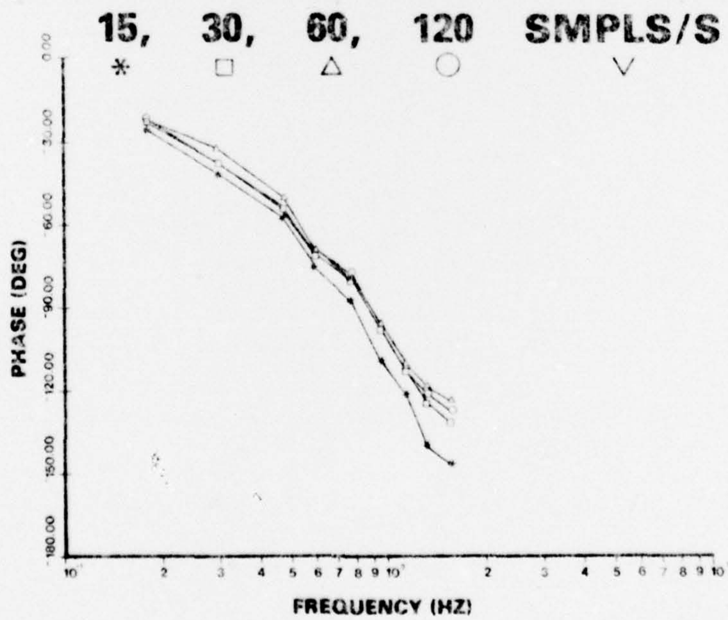

Figure 4. Vertical Phase as a Function of Update Rates

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